AXIAL BEARING ARRANGEMENT IN A HERMETIC COMPRESSOR

Field of the Invention

The present invention refers to an axial bearing arrangement in a reciprocating hermetic compressor with vertical shaft of the type used in small refrigeration systems.

Background of the Art

Hermetic compressors of refrigeration present, mounted inside a hermetically sealed shell a cylinder block, supporting a vertical crankshaft to which is mounted the rotor of an electric motor. The weight of the crankshaft-rotor assembly is supported by an axial bearing, generally in the form of a flat sliding axial bearing in which an oil film guarantees the separation of the surfaces with mutual relative movement (slipping), or in the form of a roller bearing (US4632644; WO03/019008) in which a ball assembly supports the axial weight, rolling on races that resist the Hertz tensions developed by contact with the balls.

The crankshaft carries, in its lower end, a pump rotor, which during the operation of the compressor conducts lubricant oil from a reservoir defined in the lower portion of the shell to the parts with mutual relative movement so as to guarantee oil supply for the correct operation of said parts.

The position of the axial bearing may vary according to the arrangement of the compressor components and to design variations. In some solutions, the rotor is mounted to the crankshaft below the cylinder block, as illustrated in figure 1, or the rotor is mounted to the crankshaft above the cylinder block, as illustrated in figure 2. Depending on the mounting position of the rotor in relation to the cylinder block, the surfaces that define the axial bearing are

altered.

In the situation in which the rotor is mounted below the cylinder block, the lower surface of an annular flange of the crankshaft axially journals on an annular surface defined in the upper end of the radial bearing hub. On the other hand, when the rotor is mounted above the cylinder block, the lower face of the rotor axially journals on an annular surface defined in the upper end of the radial bearing hub.

It is also known the arrangement in which a second bearing (external bearing) is provided, radially actuating on the crankshaft. In this construction in which the shaft extends beyond the eccentric part, the lower face of the annular flange can axially journal on an upper annular surface of said second radial bearing, as illustrated in figure 3 for a specific arrangement in which the rotor is mounted below the cylinder block.

In the constructions described above in relation to a sliding axial bearing, the perfect parallelism between the mutually confronting surfaces which define the axial bearing is not guaranteed due to the presence of position errors (axial strikes) and mainly deformations of the components during the compressor operation.

These errors and deformations give rise to a geometry which is unfavorable to the formation of an oil film and which consequently reduces the supporting capacity of the axial bearing, increasing the mechanical friction losses and wear to the surfaces.

The improvement of the energetic performance of these compressors can be achieved by reducing the mechanical friction losses, for example by employing more efficient bearings in the form of a roller axial bearing, whose operation in terms of dissipated

mechanical loss presents rates close to the ideal. A constructive solution of a bearing using this concept is described in Brazilian patent PI8503054 (US4632644) related to hermetic compressors in which the rotor of the electric motor is mounted above the cylinder block, as illustrated in figure 2.

The provision of a roller axial bearing as suggested in US4632644 can increase noise and reduce the mechanical reliability of the compressor, depending on the configuration of the axial bearing and on its mounting arrangement.

Co-pending document WO03/019008 of the same applicant refers to a hermetic compressor having the rotor of the electric motor mounted to the crankshaft below the cylinder block and presenting a roller axial bearing arrangement which increases the mechanical reliability of the roller bearing by minimizing the effects of crankshaft deflection, as illustrated in figure 4.

Objects of the Invention

It is a generic object of the present invention to provide a bearing arrangement in a reciprocating hermetic compressor of refrigeration, which can reduce mechanical losses and total noise levels, resulting in better energetic performance of the hermetic compressor.

It is a further object of the present invention to provide a bearing arrangement such as mentioned above, which does not impair the adequate lubrication of the crankshaft portion and of the other components of the compressor mechanism located above the axial bearing.

Summary of the Invention

The present bearing arrangement is applied to a reciprocating hermetic compressor, comprising: a cylinder block mounted inside a shell and carrying a cylinder and a vertically disposed radial bearing hub;

a crankshaft mounted through the radial bearing hub and having a first end portion projecting outwardly from the radial bearing hub and securing a rotor of an electric motor, and an opposite second end portion projecting outwardly from the radial bearing hub and incorporating a peripheral flange and an eccentric portion, the arrangement of the present invention comprising at least one magnetic axial bearing assembly composed of magnet elements with mutually confronting faces and with magnetic orientation to produce in a normal operation, support for the crankshaft sufficient to guarantee the inexistence of contact between the confronting faces of the magnet elements that define the axial bearing, each magnet element being mounted in a respective part associated with a rotating component (crankshaft or any component rigidly connected thereto, such as the rotor), and the other part being associated with a fixed component (cylinder block or any component rigidly connected thereto, such as the external bearing for example), i.e., each magnet element is mounted to a respective part of at least one of the pairs of parts of crankshaft and cylinder block and of cylinder block and rotor, there being provided, in at least one of the pairs of parts, confronting mechanical stops which are maintained spaced apart by an axial gap (FA) smaller than a magnetic axial gap (FM) existing between the confronting faces of the magnet elements, in order to guarantee that, upon occurring at least one of the conditions of a sufficiently high increase of the compressor temperature and an axial displacement of said parts during transportation of the compressor causing the mutual seating of the confronting mechanical stops, the magnetic axial gap is maintained higher than zero. Due to the presence of

the magnetic axial gap, the present invention incorporates an oil deflecting means that guarantees an ascending oil flow to lubricate the tribologic pairs located above the magnetic axial bearing.

Brief Description of the Drawings

The invention will be described below with reference to the enclosed drawings, in which:

Figure 1 is a median vertical sectional view of a reciprocating hermetic compressor with the vertical crankshaft affixed to an electric motor rotor disposed below the cylinder block and vertically supported by a prior art axial bearing;

Figure 2 is a view similar to that of the previous figure, but illustrating a prior art construction in which the rotor of the electric motor is positioned above the cylinder block and vertically supported by a prior art roller axial bearing;

Figure 3 is a median vertical sectional view of a reciprocating hermetic compressor similar to that of figure 1 and which is provided with an external bearing actuating radially on an extension of the crankshaft external to its eccentric portion and vertically supported by an axial bearing;

Figure 4 is a partial vertical sectional view of a cylinder block of the type illustrated in Figure 1 and incorporating a vertical radial bearing hub, in whose upper end a roller axial bearing is seated to the crankshaft-electric motor rotor assembly, as taught in the prior art;

Figure 5 is an enlarged and partial vertical sectional view of a cylinder block of the type shown in figure 1 and incorporating a radial bearing hub which is designed to receive a magnetic axial bearing element and an oil deflecting means constructed according to the present invention;

Figure 6 is an enlarged and partial vertical sectional view of a cylinder block of the type illustrated in figure 1, showing another construction of the oil deflecting means of the present invention;

Figure 7 is a perspective view of the deflecting means illustrated in figure 5; and

Figure 8 is an enlarged view of the mounting arrangement of the magnets illustrated in figures 5 and 6, according to the present invention.

Detailed Description of the Invention

Figure 1 illustrates, in a simplified way, a reciprocating hermetic compressor comprising a shell 10 within which is appropriately suspended a cylinder block 20, defining a cylinder 30 and incorporating a radial vertically disposed bearing hub 40 rotatively supporting a vertical crankshaft 50, having a first end portion projecting outwardly from the radial bearing hub 40 so as to secure a rotor 61 of an electric motor 60, whose stator 62 is secured under a cylinder block 20. The crankshaft 50 further presents a second end portion projecting outwardly from the radial bearing hub 40 and incorporating a peripheral flange 51, whose lower face defines an axial bearing annular surface 51a and an eccentric portion 52 to which is mounted the larger eye of a connecting rod 70, whose smaller eye is mounted to a piston 80 reciprocating inside the cylinder 30.

In this type of prior art construction, the axial bearing annular surface 51a is seated on an upper annular face 41 of the radial bearing hub 40 to thus define a sliding axial bearing which supports the load of the crankshaft 50/rotor 61 assembly.

Figure 2 further illustrates a reciprocating hermetic compressor with the same basic elements already described in relation to the compressor of figure 1

and which are represented by the same reference numbers. However, in the construction illustrated in figure 2, the electric motor 60 is disposed above the cylinder block 20 and consequently above the radial bearing hub 40.

In the construction of figure 2, a roller axial bearing 90 is provided, seated against an upper annular face 41 of the radial bearing hub 40 against a respective lower surface portion of the rotor 61.

Figure 3 further illustrates a reciprocating hermetic compressor with the same basic elements already described in relation to the compressor of figure 1 and which have the same reference numbers. However, in the construction illustrated in figure 3, an external bearing 120 is seated on the cylinder block 20 and provided so as to actuate radially on the eccentric portion 52 of the crankshaft 50. The same compressor configuration can be found when the electric motor 60 is disposed above the cylinder block 20.

In the construction of figure 4, a roller axial bearing arrangement is illustrated, which is applied to a reciprocating hermetic compressor with its crankshaft 50 being vertically disposed and carrying a rotor 61 of an electric motor mounted below the cylinder block 20 and the radial bearing hub 40.

According to the present invention, the prior art deficiencies are overcome by a magnetic bearing arrangement comprising at least one magnetic axial bearing assembly 100 composed of at least one pair of mutually confronting magnet elements 101, each magnet element 101 being mounted to a respective part of at least one of the pairs of parts of crankshaft 50 and cylinder block 20 and of cylinder block 20 and rotor 61 and there being provided, to at least one of the pairs of parts, confronting mechanical stops which are

maintained spaced from each other by an axial gap FA smaller than a magnetic axial gap FM existing between the confronting faces of the magnet elements 101 so as to guarantee that, upon occurring at least one of the conditions of a sufficiently high increase of the compressor temperature and an axial displacement of said parts during transportation of the compressor, causing the mutual seating of the confronting mechanical stops, the magnetic axial gap is maintained higher than zero.

In the construction illustrated in figure 3, the magnet elements 101 are provided between an extension of the crankshaft 50 external to the eccentric portion 52, and the external bearing 120.

Each magnet element 101 can be formed of one or more magnet portions, for example annular portions dimensioned so as to complete a closed ring in a circumferential arrangement.

In another embodiment (not illustrated), at least one magnetic axial bearing assembly 100 is formed of axially superposed magnetic rings.

In accordance with a preferred constructive form of the present invention, at least one magnet element 101 is formed in a single piece.

The magnet elements 101 present a magnetic orientation to produce a support of the crankshaft 50 which is sufficient to guarantee the inexistence of contact between the confronting surfaces of the magnet elements which define the magnetic axial bearing, the magnet elements being mounted in pairs of support surfaces, one of these support surfaces of each pair being associated with the rotating component (crankshaft 50 or any component rigidly connected thereto, for example the rotor 61) and the other support surface of each pair associated with the fixed

component (cylinder block 20 or any component rigidly connected thereto, for example the external bearing 120), there being provided, to at least one of the pairs of support surfaces, confronting mechanical stops which are maintained spaced apart by an axial gap FA smaller than the magnetic axial gap FM existing between the confronting surfaces of the magnet elements 101, so as to guarantee, upon the occurrence of axial displacements produced during transportation of the compressor or produced by temperature increases inside the compressor, the mutual seating of a pair of confronting stop surfaces and thus guaranteeing the inexistence of impact on the magnet elements 101 (the magnetic axial gap FM between the confronting faces of the magnet elements 101 never being zero).

According to the present solution, the magnet elements 101 are mounted between the axial surfaces of components with mutual relative movement, so that the latter support the axial load of the crankshaft 50/rotor 60 assembly of the electric motor 60 preventing said axial surfaces of the components with mutual relative movement (crankshaft 50 and cylinder block 10 and/or cylinder block 20 and rotor 61 and/or crankshaft 50 and external bearing 120) as well as any surfaces of the magnet elements 101 from contacting during part or the whole operating time of the compressor.

The axial force exerted on the magnetic axial bearing assembly 100 is practically constant and of low magnitude (around 12.0N), which allows using magnets of small mass (around 1.0 to 2.0g) consequently of an acceptable cost.

Both the dimensioning of the magnets and the selection of the materials should be such as to guarantee the lowest variation of the magnetic axial gap FM between

the magnet elements 101 caused by temperature variation. Also, the dimensional tolerances of the components should be the lowest possible so that the volume of the magnet elements 101, the radial mounting gap, and the axial level difference between the magnet elements 101 and said adjacent stop surfaces present the lowest variations possible. Typical tolerances for the dimensions regarding these parameters are situated around +/-0.03 to +/-0.05mm. Larger tolerances (around =/-0.02mm) can be used, but with direct consequence in the variation range of the magnetic axial gap FM.

According to one way of carrying out the present invention, at least one of the stop surfaces defines an annular sliding bearing disposed around the crankshaft 50, at least one of said stop surfaces being incorporated to one of the parts of crankshaft 50 and cylinder block 20, of cylinder block 20 and rotor 61, or crankshaft 50 and external bearing 120.

According to the illustrations, a magnet element 101 of a magnetic axial bearing assembly 100 is seated on a lowered portion of an end of the radial bearing hub 40, the other magnet element 101 thereof being seated against an adjacent surface portion of the peripheral flange 51, said radial bearing hub 40 defining a stop surface, and the peripheral flange 51 defining the other stop surface of the pair of said stop surfaces, said stop surfaces being disposed radially internally in relation to said pair of magnet elements 101 and having their axial gap FA axially leveled with the magnetic axial gap FM of said pair of magnet elements 101.

In this construction, said lowered portions guide the assembly of the magnet elements 101, defining housings for the latter, which lowered portions can, for example, retain or guide each said magnet element 101

by their respective internal diameters, which facilitates the machining process of these housings.

According to the present invention, at least one magnet element 101 is retained to one of said parts of crankshaft 50 and cylinder block 20 and cylinder block 20 and rotor 61, or crankshaft 50 and external bearing 120, by at least one of the radially internal, radially external and end faces thereof. The retention of each magnet element 101 to the respective part could be carried out by any securing means, as long as it guarantees the concentricity of said magnet elements 101 in relation to the rotating shaft of the crankshaft 50.

The depth of each lowered portion is calculated so as to assure that, even considering the dimensional variations of the magnet elements 101, the magnetic axial gap FM therebetween when mounted, is larger than the axial gap FA defined between the confronting stop surfaces where the lowered portions are located, guaranteeing that, under operation or in a transportation condition no impact will occur between the confronting magnet elements 101, neither between these and the other surfaces other than those involving each magnet element 101 in the respective lowered portion.

In the case the magnet elements 101 are mounted to the rotor 61, each lowered portion preferably guides the respective magnet element 101 by the external diameter thereof.

In another constructive variant of the present invention, at least one of the stop surfaces is defined by an insert which is secured to and projects from one of said parts of crankshaft 50 and cylinder block 20, of cylinder block 20 and rotor 61, or of crankshaft and external bearing 120, said insert being

for example a pin mounted by interference to one of said parts.

In the illustrated compressor constructions, the crankshaft 50 presents, externally, at least one helical groove in its external surface, defining a respective superficial oil channel 53 through which the lubricant oil stored in the bottom of the shell 10 is upwardly pumped. The superficial oil channel 53 presents an oil inlet lower end (not illustrated) in fluid communication with the lubricant oil inside the shell 10, and an oil outlet upper end 53a opened to the lower end of an inclined axial oil channel 54 provided along the eccentric portion 52 and which conducts lubricant oil to an end face of said eccentric portion 52.

In such types of oil pumping, special care should be taken to avoid centrifugal radial oil escapes in the region of the adjacent end of the radial bearing hub 40, which results in losses and reduction of pumping efficiency for the eccentric portion 52 of the crankshaft 50. Particularly, special care should be taken with the construction of the magnetic axial bearing disposed in this region of the radial bearing hub 40, in order to prevent the oil from leaking radially through the axial bearing region in its ascending path.

In order to avoid the centrifugal radial oil escapes, the bearing arrangement of the present invention comprises a deflecting means carried by the crankshaft 50 itself and which is disposed so as to conduct to the interior of the oil channel 54, most of the ascending oil flow reaching the oil outlet upper end 53a of the superficial oil channel 53, minimizing the centrifugal radial escapes of said ascending oil flow in the region of the adjacent end of the radial

bearing hub 40.

The deflecting means makes that part of the radial oil flow received therein to be forced to flow upwardly, penetrating in the oil channel 54 by its radially and axially opened lower portion and being elevated till the top of the eccentric portion 52.

Figures 5 and 6 illustrate a first embodiment for the bearing arrangement of the present invention which prevents the oil from leaking between the magnet elements 101 disposed between the parts of crankshaft 50 and cylinder block 20.

In this illustrated constructive form of the present invention, the deflecting means is in the form of a conduct 110 disposed inside the oil channel 54, having an end 111 opened to the oil outlet upper end 53a of the superficial oil channel 53 and an opposite end 112 opened to the inside of the internal oil channel 54, the end 111 being axially spaced from a lower plane of the magnetic axial gap FM between said magnet elements 101.

For mounting the conduct 110 inside the oil channel 54, the former carries, in its opposite end 112, an expanding portion 113 in the form of an arc which is resiliently forced to a compressing condition so as to mount the conduct 110 inside the oil channel 54, said condition being maintained by the seating of an external surface of said expanding portion 113 against an internal surface of the oil channel 54.

In another embodiment of the present invention illustrated in figure 7, the deflecting means is defined by an axial wall portion 55 of the crankshaft 50, provided between the oil outlet upper end 53a of the superficial oil channel 53 and the lower end of the oil channel 54 of the eccentric portion 52, said axial wall portion 55 extending along the crankshaft

50 at least in the region of the adjacent end of the radial bearing hub 40. In a way of carrying out the present invention, the oil channel 54 has part of its extension provided inside the crankshaft 50.

In the construction illustrated in figure 7, the present arrangement further comprises an oil passage 56 defined inside the crankshaft 50 and which is internal to and spaced from the peripheral contour of the latter, having an upper end portion opened to the upper end of the oil channel 54 and a lower end portion opened to the oil outlet upper end 53a of the superficial oil channel 53, the peripheral contour of at least one of the parts of oil passage 56 and oil channel 54 defining an internal contour for the axial wall portion 55.

While only one construction in which only one pair of magnet elements 101 are provided between the cylinder block 20 and the crankshaft 50 has been illustrated, the present arrangement also applies to the parts of cylinder block 20 and rotor 61, or to the parts of crankshaft 50 and external bearing 120, whether separately or simultaneously.

Depending on the dimensions of the compressor components, it is possible for the minimum dimensions of the magnet elements 101 for a given magnetic material to present a very high supporting capacity, resulting in very large mechanical gaps (FA) and magnetic axial gaps (FM). The adjustment of this supporting capacity of the magnet elements 101 can be obtained by mixing the magnetic material with polymers by processes, such as metal injection (injection molding).

Although not illustrated, other configurations for the bearing arrangement within the concept presented and claimed herein are possible, for example with

arrangements in which the pairs of magnet elements 101 are provided axially spaced from the stop surfaces in relation to which said pair of bearings are operatively associated.

With the bearing arrangement of the present invention, a better energetic and acoustic performance of the compressor is attained, reducing the mechanical losses and noise levels of the compressor.